

Characterization and Management of Mandibular Fractures

Lessons Learned from Iraq and Afghanistan

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KEYWORDS

• Mandible • Fracture • Combat-related injury

KEY POINTS

- Proper treatment cannot be completed without an accurate diagnosis.
- Whenever possible, occlusion should be used to guide reduction.
- Anatomic reduction is the goal.
- In complex fractures, maintain large segments of bone and obtain soft tissue coverage.

Introduction

The ongoing wars in Iraq and Afghanistan have provided the oral and maxillofacial surgeon unique challenges in reconstructing and restoring function to these soldiers with complex facial injuries. Indeed, injuries that were unsurvivable in previous conflicts are now commonplace because of early surgical intervention, body armor, and rapid evacuation. This article examines the history, etiology, diagnosis, classification, treatment, and complications of mandibular fractures, with emphasis on the challenges in treatment of facial injuries associated with blast and penetrating injuries common in Iraq and Afghanistan.

History

Archeological evidence shows humans have survived complex mandibular fractures long before they were documented in written history.¹ The first writings appeared as early as 1650 BC, but it was Hippocrates who first developed the concept of reapproximation and immobilization in 400 BC.² The development of

our current practice has been slow, with the importance of occlusion first introduced in 1180.³ Certainly, until the late 19th century, fixation of fractures centered on monomaxillary wiring and external bandages.

Hippocrates said, "War is the only proper school for a surgeon." Indeed, many major advances in treating maxillofacial injuries have arisen from conflicts.

The United States Civil War resulted in the next major technological advance in treating mandibular fractures—the use of interdental splints and intermaxillary fixation.⁴ Thomas Brian Gunning⁴ showed the importance of dentistry in treating these fractures by restoring occlusion with vulcanite splints.

During World War I, further advancement in treatment was pioneered by Kazanjian, who began wiring segments of bone together in combination with intermaxillary fixation.⁵ The external fixator, developed in 1936, was widely in use during World War II and continues to be useful in complex mandibular fractures.⁵ Internal fixation as we know it would be impossible without the development of safe antibiotics in the 1940s.

From the 1960s to the present, the focus in treatment of mandibular fractures has focused on internal fixation. Early treatment focused on large bulky plates placed through extraoral incisions. Over time, technology has resulted in smaller plates placed through intraoral incisions, which are effective in many fractures.^{6–8} Current technology seems focused on resorbable plates composed of copolymers of D- and L-lactic acid. Titanium and biodegradable miniplates are now often used in place of larger reconstruction bars with good success.^{8,9}

Combat-related maxillofacial injuries are primarily caused by explosives. The mandible is most commonly injured, with open fractures 3 times more common than closed fractures. These injuries are difficult to classify, and treating these often avulsive, penetrating, and burn injuries presents new challenges in our field (Fig. 1).^{10,11}

The wars of Iraq and Afghanistan will continue to challenge our capabilities as oral and maxillofacial surgeons. These

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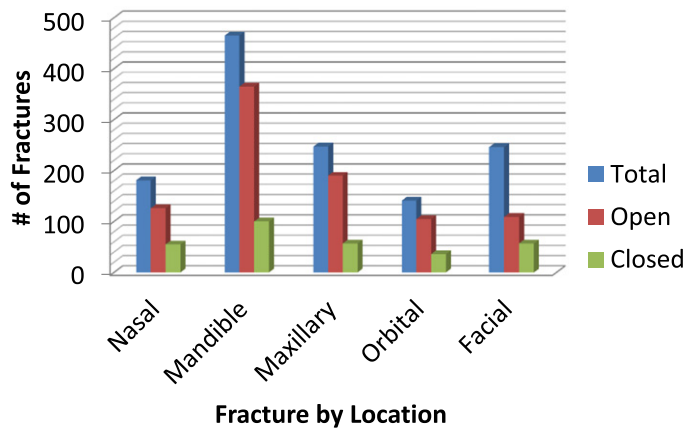


Fig. 1 Distribution of combat-related craniomaxillofacial fractures in Operation Iraqi Freedom and Operation Enduring Freedom from October 2001 to December 2007. (Adapted from Lew TA, Walker JA, Wenke JC, et al. Characterization of craniomaxillofacial battle injuries sustained by United States service members in the current conflicts of Iraq and Afghanistan. *J Oral Maxillofac Surg* 2010;68(1):3–7; with permission.)

injuries often involve complex burns and devastating tissue loss. The care of these patients will usually require multiple surgeries and coordination with critical care, neurosurgery, plastic surgery, anesthesia, and frequently psychiatry, speech therapy, and prosthodontics. Advances in regenerative medicine, wound healing, and even composite tissue allografting may be the future of treatment in these demoralizing injuries.

Etiology of mandibular fractures

Early analysis of data by Zachar and Lew (Zachar MR, Labella C, Kittle CP, et al. Characterization of mandible fractures incurred from battle injuries in Iraq and Afghanistan from 2001–2010. Submitted to *J Oral Maxillofac Surg*) shows that the current system of facial injury classification is inadequate. The current coding system is insufficient in reporting the amount of tissue loss, burns, and atypical fracture patterns found in war injuries. A better system of reporting these injuries may improve care and decrease the number of procedures for these patients.

Mandible fractures are among the most frequently encountered types of facial injury in developed and undeveloped countries. The cause is usually by violent crime (assault) or motor vehicle accidents. Classification varies but minimally should include number of fractures, relationship to external environment, presence of teeth, and location (Figs. 2–5).

When comparing battle injuries in Afghanistan and Iraq with civilian trauma, fractures involving the mandibular body and angle are significantly higher in the battle-injured population (Fig. 6). This is because of the nature of blast injury forces compared with those of blunt trauma (Zachar MR, Labella C, Kittle CP, et al. Characterization of mandible fractures incurred from battle injuries in Iraq and Afghanistan from 2001–2010. Submitted to *J Oral Maxillofac Surg*).

Fracture classification by anatomic region

- Midline—fracture between central incisors³
- Parasymphyseal—fractures occurring within the area of the symphysis

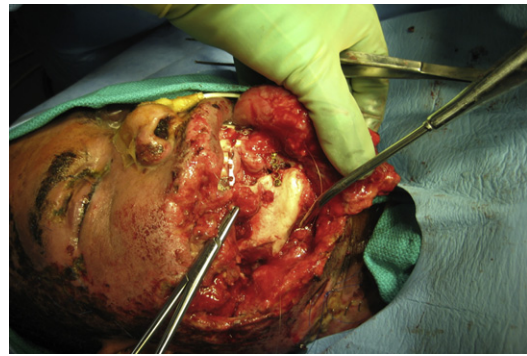


Fig. 2 Complex facial injury with avulsive tissue loss. Many combat injuries result in burns, significant tissue loss, and exposed bone.



Fig. 3 Avulsive injury caused by explosive. Note loss of commisure, upper and lower lip defects, and burn eschar.

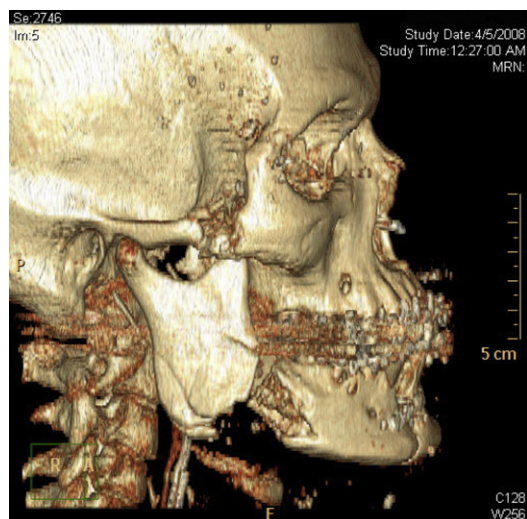


Fig. 4 Three-dimensional CT of patient in Fig. 2. Note avulsion of large segment of mandibular body.

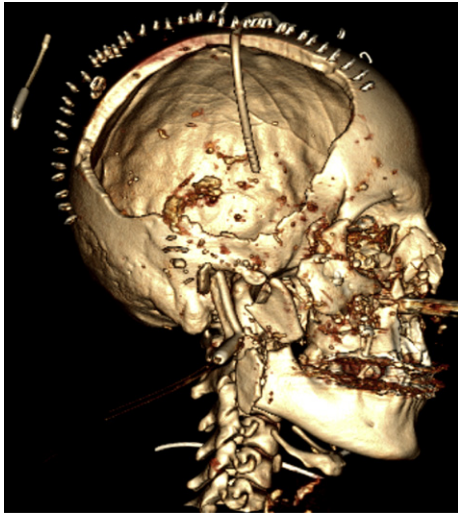


Fig. 5 Three-dimensional CT of patient in Fig. 3. Note extensive comminution typical with explosive injury to the face.

- Symphysis—bounded by vertical lines distal to the canine teeth
- Body—from the distal symphysis to a line coinciding with the alveolar border of the masseter muscle
- Angle—triangular region bounded by the anterior border of the masseter muscle to the posterosuperior attachment of the masseter muscle
- Ramus—bounded by the superior aspect of the angle to 2 lines forming an apex at the sigmoid notch
- Condylar process—area of the condylar process superior to the ramus region
- Coronoid process—includes the coronoid process of the mandible superior to the ramus region
- Alveolar process—the region that would normally contain teeth (Fig. 7)

Common descriptive terms of fractures

- Simple (Closed)—fracture without wound open to external environment¹²

- Compound (open)—fracture in which an external wound, involving skin, mucosa, or periodontal membrane, communicates with the break in the bone
- Comminuted—fracture in which the bone is splintered or crushed
- Greenstick—fracture in which only one cortex of the bone is fractured
- Pathologic—fracture occurring due to presence of disease
- Multiple—2 or more lines of fracture on the same bone not communicating with each other
- Impacted—a fracture in which one fragment is firmly driven into another
- Atrophic—fracture resulting from atrophied bone
- Indirect—a fracture at a point distant from the site of injury
- Complicated (complex)—fracture with considerable injury to the adjacent soft tissue or adjacent parts, may be simple or compound

Shetty and colleagues¹³ recognize the lack of objectivity and standardization with our current methods of characterizing mandibular fractures. They have developed the UCLA Mandible Injury Severity Score to numerically classify the severity of injury and guide treatment. Unfortunately, this analysis eliminated complex injuries like gunshot wounds, so its use for characterizing battle injuries would be limited.

Fractures involving the condyle should be considered separately. Multiple classification systems have been proposed, but generally they are classified as intracapsular, extracapsular, or subcondylar. Degree of displacement and comminution will generally dictate treatment.

Diagnosis/evaluation

A thorough history and physical examination are performed once the airway is secured and the patient is hemodynamically stable. The history can provide clues to the types of injuries expected, changes in occlusion, and medical issues that may influence treatment.

Palpation of the condyles and inferior border of the mandible will find obvious fractures, whereas the intraoral examination will find malocclusion, missing teeth, range of

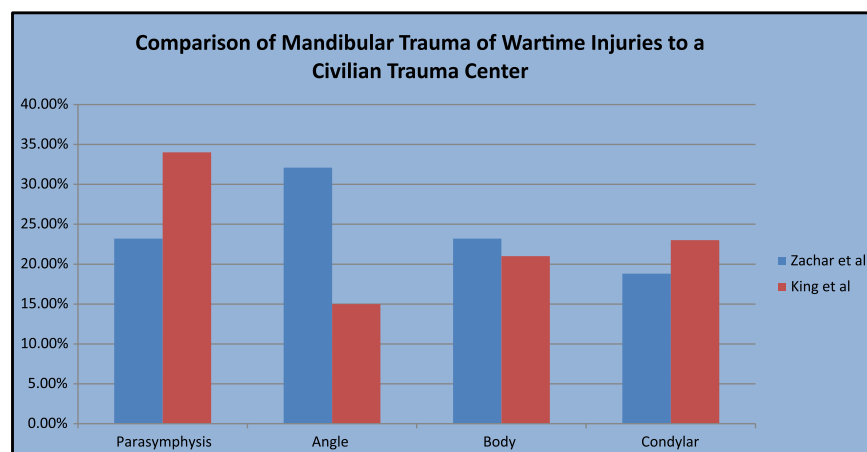


Fig. 6 Comparison of mandibular trauma of combat-related injuries (blue) with those in a civilian trauma center (red).



Fig. 7 Anatomy of the mandible: Fractures are named according to the portion of the mandible through which they pass. From medial to lateral: symphyseal, parasymphysal, body, angle, ramus, subcondylar, condylar, coronoid process above angle/ramus. (From Follmar KE, Baccarani A, Das RR, et al. A clinically applicable reporting system for the diagnosis of facial fractures. *Int J Oral Maxillofac Surg* 2007;36(7):593–600; with permission.)

motion, and vestibular or sublingual ecchymosis. Traction on the anterior mandible will elicit pain in the fracture sites. If the patient is conscious, a neurologic examination will find sensory deficits or motor deficits when there is injury or interruption to the trigeminal or facial nerves.

Simple mandibular fractures can be imaged by the panoramic radiograph. Plain films are of limited value, as images are frequently superimposed and the condyles are difficult to view. When teeth or teeth fragments are unaccounted for, chest x-ray and KUB (an x-ray of the kidneys, ureter, and bladder) films should be taken to rule out aspiration. The computed tomography (CT) scan is invaluable in evaluating condylar fractures and complex mandibular fractures. Three-dimensional reconstruction and stereolithographic models are especially helpful in injuries in which hard tissue is missing or grossly displaced. A comprehensive plan to restore occlusion and continuity of the mandible may include the fabrication of lingual or occlusal splints for use intraoperatively (Box 1, Figs. 8 and 9).

Management

There are 3 basic types of treatment for mandibular fractures: closed reduction, open reduction with internal fixation, and external fixation (Box 2).

Nondisplaced mandibular fractures without occlusal disturbances can be treated with a nonchewing diet. When occlusal disturbances are present and a fracture is minimally displaced, treatment can be the application of intermaxillary fixation for a period of 2 to 3 weeks, depending on the patient's age, health, and fracture type. Displaced fractures generally require open reduction with internal fixation using titanium screws and plates. Because of the high infection rate of open fractures, these should be treated with antibiotic prophylaxis. General anesthesia and paralytics are useful in



Fig. 8 Gunshot wound to mandible. Despite minor external tissue injury, there is extensive comminution of the mandibular body.



Fig. 9 Axial CT shows extensive fragmentation of right mandibular body from patient in Fig. 8.

Box 1. Clinical indicators of mandibular fracture

- Occlusal changes
- Abnormal opening/deviation
- Anesthesia/paresthesia/dyesthesia
- Vestibular or floor of mouth ecchymoses
- Facial asymmetry
- Loose or fractured teeth

Box 2. Goals of mandibular fracture treatment

- Restore facial contours
- Restore arch form
- Restore occlusion
- Restore function

Table 1 Techniques for closed reduction

Technique for Closed Reduction	Advantage	Disadvantage
Arch bars	Ability to reduce several segments at once, multiple areas to wire into IMF	Time consuming, potential for skin puncture, difficult to remove
Orthodontic brackets	Saves time in operating room, patient comfort	Debond easily, requires orthodontist appointment
Ivy loops	Speed in application, useful for minimally displaced favorable fractures	Less useful with multiple fractures, less control of individual segments
Intermaxillary fixation screws	Speed in application, ease in removal	Cost, potential damage to tooth roots, screws may loosen

reduction, as this will minimize the muscle pull on unfavorable fractures.

Indications for closed reduction of mandibular fractures

- Nondisplaced favorable fractures³
- Grossly comminuted fractures
- Fractures with avulsed tissue—Devascularized bone has limited ability for healing. Placement of plates and screws may further strip the blood supply of these fragments. If possible, flaps should be rotated to improve blood supply to large segments of exposed bone.
- Fractures in children with developing dentitions—Avoiding damage to the developing teeth is key. If placement of arch bars is impossible, consideration should be given to a lingual splint and skeletal fixation with circummandibular and piriform wires.
- Coronoid process fractures
- Condylar fractures—Closed reduction is useful when the occlusion can be reduced and the fracture is minimally displaced.

Treatment with closed reduction

Multiple options are available for reducing the teeth into occlusion via intermaxillary fixation. The most common methods are listed in [Table 1](#).

Indications for open reduction of mandibular fractures

- Displaced unfavorable fractures of the body or parasymphysis³
- Multiple fractures including the midface
- Bilateral condylar fractures
- Edentulous mandible fractures
- Edentulous maxilla with mandible fracture
- When intermaxillary fixation is contraindicated—Open reduction and internal fixation should be considered the preferred treatment in patients with poorly controlled seizures, severe psychiatric or mental impairment, respiratory disorders, or severe nutritional disorders.

Indications for external fixation

- Grossly comminuted fractures—external fixation allows the stabilization and gross approximation of the mandibular segments without compromising the blood supply of small and large bone fragments.

Surgical approach

- Dictated by location and degree of displacement, condition of bony fragments
- Body, angle, and symphysis can usually be plated through vestibular incisions
- Consider extra-oral approach for significantly displaced fractures ([Table 2](#)).

Special considerations for complex open fractures

- Small, devitalized fragments of bone should be removed¹⁴
- Larger fragments should be reduced and fixated
- Use intermaxillary fixation (IMF) to align dentoalveolar fragments
- Cover exposed bone when possible
- Delayed grafting with a healthy, infection-free tissue bed if necessary
- Consider osseous free flap for defect greater than 6 cm
- Open fractures of the mandibular body—this area is exceptionally difficult to treat. Comminution and significant displacement frequently interrupt the centripetal blood supply of the inferior alveolar vessels and make this area especially prone to infection and necrosis ([Figs. 10–17](#)).

Table 2 Surgical approaches to mandibular fractures

Surgical Approach	Region Accessed	Benefits	Complications
Submandibular	Body/Angle	Excellent visualization of inferior border	Scarring, potential facial nerve injury
Preauricular	Temporomandibular joint	Ability to fixate condylar head, restore vertical height of posterior mandible	Scarring, potential facial nerve injury
Retromandibular	Neck of condyle	Ability to fixate subcondylar fracture, restore vertical height of posterior mandible	Scarring, potential facial nerve injury
Vestibular/ intraoral	Symphysis, parasymphysis, body, and angle	No facial scarring, avoids facial nerve	Difficult to visualize inferior border and lingual plate



Fig. 10 Initial treatment of this patient included debridement of devitalized bony fragments, stabilization of teeth in arch bars, and reapproximation of tissues to cover exposed bone.



Fig. 11 Patient after initial debridement and soft tissue reapproximation.



Fig. 12 To preserve blood supply to the mandible, an external fixator is applied to stabilize the bony fragments.



Fig. 13 Integra matrix wound dressing is applied to provide scaffold for capillary growth and support of split thickness skin graft.



Fig. 14 Wound healing after maturation of skin graft.

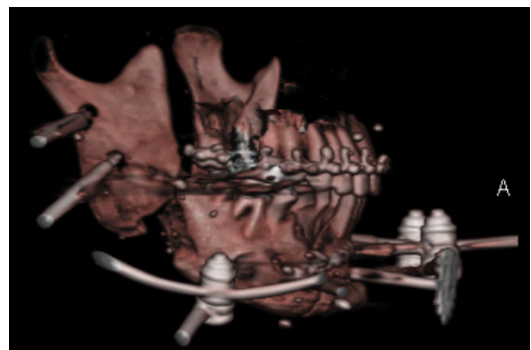


Fig. 15 After initial bone healing, a large defect of the mandibular body remains with minimal bony union.

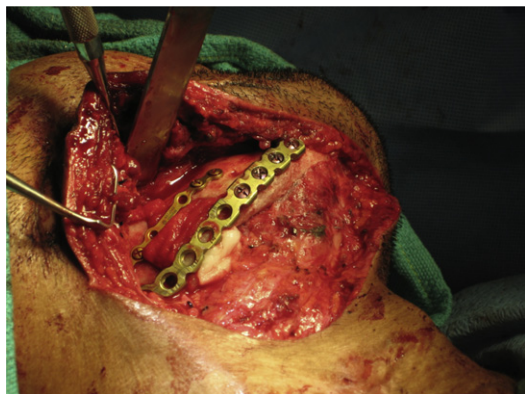


Fig. 16 External fixator is removed and mandible reconstructed with Bone morphogenetic protein.

Complications

Complications of mandibular fractures are fairly common, with a wide range of infection rates reported (between 4% and 50%).¹⁵ These complications include infection, osteomyelitis, malunion, nonunion, and nerve disturbances. Contributing factors to complications include teeth in the line of fracture, antibiotic use, compliance of patient, and substance abuse.^{16,17} In a prospective study, Chole and Yee¹⁸ found that prophylactic antibiotic use is shown to reduce the risk of infections in facial fractures from 42.2% to 8.9%.

Avulsive, comminuted wounds, or those with diminished blood supply, should be considered separately. Fractures in which the central blood supply of the mandible has been interrupted are particularly troublesome and prone to resorption, nonunion, and necrosis. A prolonged course of antibiotic therapy is indicated in these especially infection-prone patients.^{19,20}

- **Infection**—the most commonly encountered complication of mandibular fractures, especially in complex fractures. Infections in mandibular fractures are generally polymicrobial and are more common when teeth are involved in the line of fracture.¹⁶ Incision and drainage should be performed if the infection is localized to the surgical area. Rigid fixation should be maintained for 4–6 weeks, at which point the hardware can be removed. If the infection involves loose bony fragments or hardware, they should be removed until bleeding bone can be visualized. Rigid

fixation should be applied through a reconstruction plate or external fixator.

- **Nonunion** occurs when a fracture fails to heal within 6 months. This is caused by infection or mobility at the fracture site.
- **Malunions** occur when the bone heals, but malocclusion results. Orthodontics should be considered for minor occlusal changes. A full orthognathic surgery workup is indicated for major occlusal discrepancies.
- **Nerve injury** to the inferior alveolar nerve or mental nerves is common. Less commonly, the facial nerve can be injured during extra-oral access to fractures. Nerve injuries should be monitored for resolution. These patients should be treated medically if they develop dyesthesia and referred to a specialist if their symptoms do not improve.

Summary

Fractures of the mandible are among the most common facial injuries. Invasiveness of treatment should be determined by the extent of injury: degree of displacement, number of fractures, the patient's health status, and concomitant injuries. Complex, comminuted, and avulsive injuries frequently seen in combat will require coordination with multiple specialties to provide the best treatment. Stabilization treatment with arch bars or external fixators and splints is often desirable when fractures are highly comminuted or the soft tissue envelope is compromised by tissue loss or burns. In severe injuries, many times reconstruction will take several surgeries. Debridement of necrotic tissue and devascularized bone and skin grafting often are necessary before reconstruction. Microvascular or myocutaneous flaps should be considered with significant tissue loss and osteocutaneous flaps when large continuity defects are present.

Most mandible fractures are repaired in a single operation. Those caused by explosives and high-velocity projectiles are more complex. Research should continue to focus on improving outcomes for these patients. Advances in tissue engineering, bone regeneration, and composite tissue allografting will have to continue if we hope to restore facial form and function for our combat wounded.

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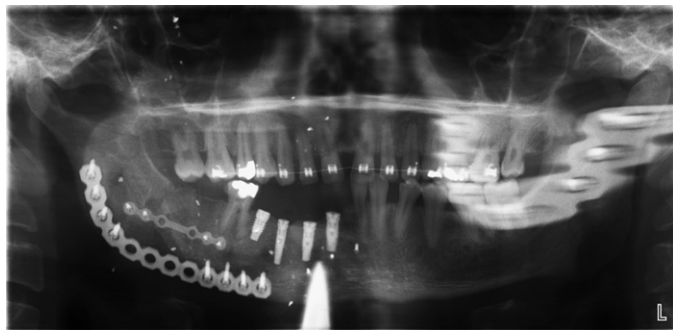


Fig. 17 Final reconstruction with dental implants.

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